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AUTHORITY
USNMRL ltr., 13 Jul 1967

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AD-159 358

U.S. NAVAL
MEDICAL RESEARCH LABORATORY



Submarine Base, New London, Conn.

Vol. XVI, No. 7

REPORT NO. 285

14 June 1957

PILOT STUDIES OF A SCOTOPIC SENSITIVITY TEST

by
Gilbert Fooks,
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Bureau of Medicine and Surgery, Navy Department
Project NM 23 01 20

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U.S. Naval Medical Research Laboratory Report No. 285

Bureau of Medicine and Surgery, Navy Department
Project NM 23 01 20
Report No. 1 on Subtask 4

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SUMMARY PAGE

THE PROBLEM

To ascertain certain preliminary conditions affecting the nature of the test under construction for determination of scotopic sensitivity, that is,

- (1) whether a sampling procedure would give as valuable a result as the longer psychophysical techniques;
- (2) whether reliable differences in individual scotopic sensitivity could be demonstrated;
- (3) whether multiple stimuli could be presented as a time saving device; and
- (4) whether one or two testing sessions would give adequate scores.

FINDINGS

Sensitivity scores derived from a sampling procedure correlate well with the psychophysical findings. Significant individual differences in sensitivity were shown to exist. Multiple stimuli can be used and do not produce any decrement in the sensitivity scores. Two testing sessions serve to differentiate individuals adequately.

APPLICATION

The information gained in these studies will be useful in the construction of the final version of a test for scotopic sensitivity. This material, together with the findings reported in earlier studies made by this Laboratory, form the basis of a more satisfactory and reliable test of scotopic ("night") sensitivity.

ADMINISTRATIVE INFORMATION

This investigation is a part of Bureau of Medicine and Surgery Research Project NM 23 00 00 — Assessment of Personnel for Duty in Undersea Warfare, Task 23 01 20, Psychophysiological evaluation of personnel for submarine duty and other underwater duty, Subtask 4, Visual performances and requirements in submarine and other underwater operations. This report is Report No. 1 on the above subtask and was approved for publication on 14 June 1957.

Published by the Naval Medical Research Laboratory
For Official Use

ABSTRACT

A new test of night vision sensitivity has been devised, that is based on data obtained in a series of experiments reported by this Laboratory. Those findings indicated (1) that sensitivity in the visual field must be sampled in two dimensions; and (2) that size and brightness of the test areas can be used interchangeably.

The present preliminary studies were designed to determine (1) whether a sampling procedure would give the same indication of the distribution of sensitivity as the more extended psychophysical techniques; (2) whether reliable differences in individual scotopic sensitivity were indicated; (3) whether multiple stimuli could be presented as a time-saving device; and (4) whether one or two testing sessions would give an adequate score.

The results show (1) that the sensitivity scores correlate well with the psychophysical findings; (2) that significant individual differences in scotopic sensitivity exist; (3) that multiple stimuli do not produce any decrement in the sensitivity scores; and (4) that two testing sessions serve to differentiate individuals adequately.

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PROBLEM

The pilot studies presented in this report were undertaken as part of a program of developing a test of scotopic sensitivity. The purpose of this program is to find a more satisfactory means of evaluating the night vision of service personnel.

The unique feature of the new test is that it arrives at a representative picture of an individual's scotopic sensitivity by sampling a number of retinal locations. The sampling is made along three dimensions; stimulus size, radial position, and degrees from fixation; these three variables have been found to be important conditions of retinal sensitivity for the dark adapted eye.

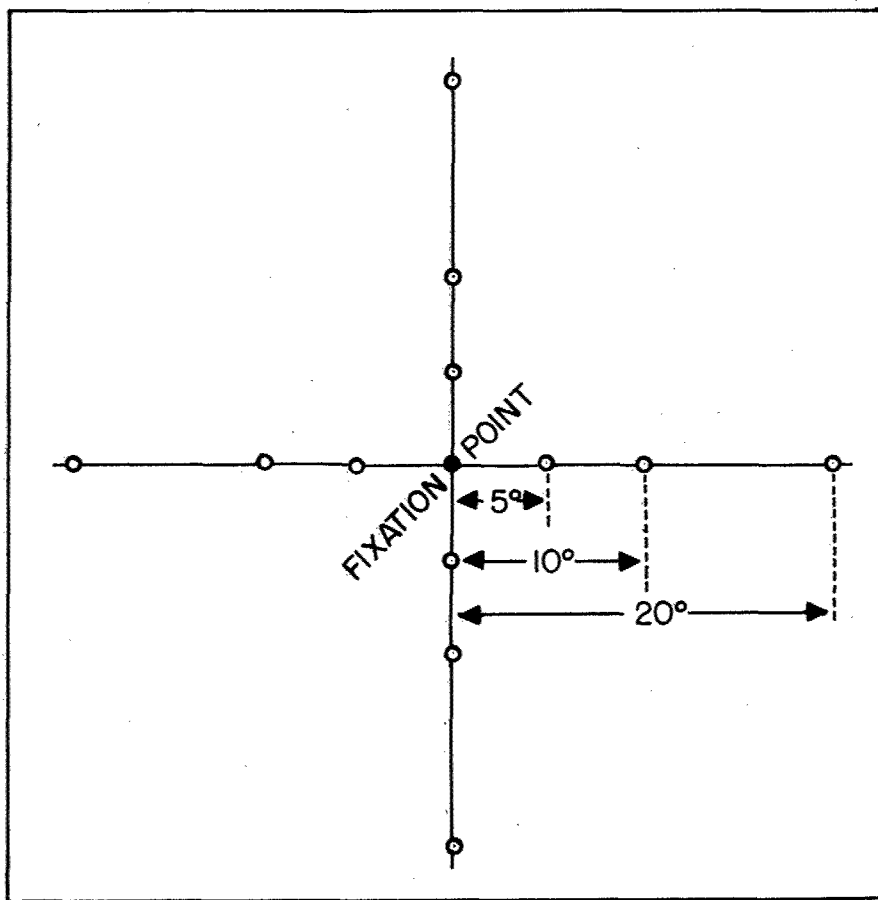
The studies were conducted with several

objectives in view. One of these was to establish the relevance of the test to night vision by showing that the results of scotopic sensitivity established in earlier experimental studies ^{1, 2, 3} could be confirmed with scores on the test. A second objective was to determine whether the test was capable of differentiating individuals who were sophisticated in psychophysical observation and who could be tested without time limit. Finally, we sought to evaluate two aspects of the problem in the construction of the test: (1) the feasibility of asking observers to judge the presence of several simultaneous stimuli was determined; and (2) an examination was made of the minimum number of sessions required for reliable measurement.

DESCRIPTION OF THE TEST

The observer sits in a dark booth while being tested, his chin steadied on a rest and his left eye occluded. He looks directly ahead, 28.6 inches, at a fixation point in the center of a panel 23 inches square. The light for fixation is transmitted through a red plastic filter with a cut-off at 590 m μ ; it has a diameter that subtends 12 minutes

of visual angle, and is adjustable in brightness to be just easily seen by the observer. The panel contains an array of twelve holes through which light can be presented. The arrangement of the holes is shown in the accompanying diagram. On each trial the number, size, and position of exposed stimulus spots are controlled by card inserts



which bear apertures cut to size, to admit light, or to block it, from the twelve positions cut in the master panel. More specifically:

(1) One, two, three or four stimuli are presented at a time.

(2) The apertures through which the light shines are varied in five steps between 0.160 and 0.281 degrees of visual angle.

(3) There are twelve locations at which stimulus spots may appear. Three positions are located on the vertical meridian above the fixation point, three are

located below, three are on the horizontal to the right and three are to the left. Four of the stimulus spots appear at a distance of five degrees from the fixation point, four are ten degrees away, and four are twenty degrees away.

The brightness of the source is not varied. The panel and cards cover a circular window 22 inches in diameter cut from an integrating sphere, 34 inches in diameter. A shielded 7-watt bulb illuminates the interior of the sphere, producing a uniform brightness of 4.986 log μL at every aperture. The source is operated at constant voltage.

PROCEDURE

The observers used in these studies are members of the laboratory staff**. They are all highly trained, in the age range from 25 through 32, and all have normal night vision. All have had extensive experience in making psychophysical judgments.

The testing began after 30 minutes of dark adaptation. Each trial started with the appearance of the fixation light; after a ready signal, the stimulus was exposed, and the observer reported what he had seen.

In the first study, the stimulus duration was two seconds. Three stimuli were presented on every trial at different radial positions and degrees from fixation. The observer

reported the radial position and distance from fixation in terms such as "Up-in", "Down-middle", "Right-out", etc. In one session the observer made sixteen judgments at each of five stimulus sizes. Each observer was given nine sessions.

In the second study, the stimulus duration was three seconds. All stimuli appeared ten degrees from fixation, but a varying number was presented, from one through four, though only one at a time in a given radial position. The observer reported the radial position of the stimuli. In each session, 29 observations were made at each of four stimulus sizes. Ten sessions were given to each observer.

** Their names are: G. Fooks, P. Kelsey, J. Kinney, A. Ryan, I. Schwartz, E. Sweeney and R. Wienke.

RESULTS AND DISCUSSION

The results can most conveniently be presented under headings that represent the three objectives of the pilot studies.

(1) Relevance of the test as a measure of scotopic sensitivity.

In earlier experimental studies of scotopic sensitivity, it was established that fixation distances of ten degrees have associated with them much lower limens than those of five

TABLE I. Fifty percent limens, measured in degrees of visual angle, at twelve locations in the field, for six observers combined.

Fixation Distance	Radial Position				Average
	Temporal	Nasal	Down	Up	
5°	.188	.226	.202	.212	.207
10°	.185	.168	.184	.193	.182
20°	.297	.207	.304	.289	.274
Average	.223	.200	.230	.231	

degrees and twenty degrees, and that there are negligible differences among the four radial positions ^{1,2}.

A similar picture is found in the test results presented in Table I¹. The limens in this table are points of fifty percent response, in stimulus size units, derived from frequency of seeing curves for the combined data of six observers, with nine sessions each. If these limens are given ranks from one to twelve, and if ranks are assigned to the corresponding data from the earlier study¹, the rank order correlation between the sets of data is 0.71. This degree of correlation was achieved despite the use of different observers and different apparatus[#] in the two studies.

On the whole, it may be concluded that results with the present test corroborate results of earlier studies, and that the test is

a relevant measure of scotopic sensitivity.

(2) Effectiveness of the test in differentiating trained observers.

In both studies it was possible to establish significant individual differences in overall scores on the test. The significance of the individual differences, when the individual's score is the average of his mean limens at three fixation distances, combining data for all radial positions, is established in Table II.

TABLE II. Analysis of variance to test significance of individual differences and fixation distance.

Source	Sums of Squares	Degrees of Freedom	Variance Estimate	F ratio	Probability of a larger F
Individuals	6107.11	5	1221.42	8.93	P < .01
Fixation distance	27894.11	2	13947.06	101.96	P < .01
Remainder	1367.89	10	136.79	-	-
Total	35369.11	17	-	-	-

Table III contains a test of significance of individual differences, like the one in Table II, except that it is based on the average of limens derived from frequency of seeing functions for the four radial positions with data for all fixation distances combined. Again, individuals have been differentiated to a significant degree with the test of scotopic sensitivity.

TABLE III. Analysis of variance to test significance of individual differences and radial position.

Source	Sums of Squares	Degrees of Freedom	Variance Estimate	F ratio	Probability of a larger F
Individuals	8503.38	5	1700.68	7.19	P < .01
Radial Position	1975.46	3	658.49	2.78	P > .05
Remainder	3547.79	15	236.52	-	-
Total	14026.62	23	-	-	-

† For tests of the significance of differences in fixation distance and radial position see Tables II and III.

A flat field was used in this test while a perimeter-type was employed in the previous experiments. This accounts, at least in part, for the fact that the chief inconsistency between the two sets of data is that the 20° positions were generally less sensitive than the 5° positions in this study while in the previous data there was little difference between the two.

When scores are simple counts of the number of stimuli seen, scores based on the results of the first two sessions suffice to differentiate individuals at the five percent level of significance. Table IV contains an analysis of variance relating to this point, based on information obtained in the second study. The data on which the analysis is

TABLE IV. Analysis of variance to test individual differences in total stimuli seen for first and second sessions combined.

Source	Sums of Squares	Degrees of Freedom	Variance Estimate	F ratio	Probability of a larger F
Individuals	284.21	5	56.84	3.52	$P < .05$
Stimulus Size	9257.79	3	3085.93	191.32	$P < .01$
Remainder	241.96	15	16.13	-	-
Total	9783.96	23	-	-	-

based, are the total number of stimuli seen by each observer at each stimulus size, for the first and second sessions combined.

(3) Feasibility of making abbreviations in the test.

In these studies, observers spent nine or ten sessions being tested. Each session required a half hour for becoming dark adapted and an hour for testing. That is a total of thirteen to fifteen hours for each observer. No practical test for mass administration can occupy so much time. The problem is to find a shorter version, without impairing the quality of the test.

It has already been shown in Table IV that two sessions sufficed to differentiate individuals when scores were simple counts of the total number of stimuli seen. Under the conditions of this study, it is not possible to measure individual differences in only one session: if scores for the first session by itself are analyzed along lines of Table IV, the variance ratio for individual differences is 2.72 and is not significant at the .05 level.

There is a high degree of consistency in the measurement based on two sessions. Table V shows that the six individuals could have been ordered on the basis of performance after two sessions, in a way almost

TABLE V. Scores and ranks of individuals on the basis of the first two sessions, and of all ten sessions combined.

Observer	First two sessions		All ten sessions	
	Mean Score	Rank	Mean Score	Rank
GF	80	1	81	2
IS	78	2	85	1
PK	74	3	76	3
ES	70	4	73	4
JK	65	5	68	5
AR	60	6	63	6

(The scores in this table are the average number of stimuli seen per session, combining all stimulus sizes and radial positions. If an individual had seen all stimuli of all four sizes, on all presentations, his score for a session would be 116.)

identical with the way they were ranked after ten sessions.

One of the major economies to be employed in the proposed test is the collection of several judgments on each trial. When this possibility was evaluated experimentally, it was found that multiple presentations do not adversely affect the difficulty of the task; on the contrary, as Table VI shows, the more stimuli presented in the field, the more likely each is to be seen.

TABLE VI. Percent of times, for six observers, that each stimulus is seen when presented simultaneously with stimuli in other meridians.

Diameter of Stimulus Spot	Number of other stimuli simultaneously presented			
	None	One	Two	Three
.070°	13%	14%	18%	15%
.100°	45	56	64	65
.130°	79	84	91	92
.160°	90	92	96	96

(The base of the percentages in this table is 208 for each of the percentages in the first and last column, 624 for those in the second column and 486 for those in the third column.)

CONCLUSIONS

It has been found that when administered under carefully controlled conditions, the new test being developed at this laboratory is a relevant and reliable measure of individual differences in scotopic sensitivity. It

was found feasible to reduce the testing period to two hours, and to ask the observer to judge the presence or absence of at least four stimuli on each trial.

ACKNOWLEDGMENT

We wish to acknowledge the considerable contribution of Harold P. Van Cott, a former member of the Vision Branch's Staff, to the studies in this report. The scotopic sensi-

tivity test was constructed, with few modifications, from a design which he originated and developed, after extensive trial of other models.

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Accession No.	Unclassified	Accession No.	Unclassified
<p>U.S. Naval Medical Research Laboratory, U.S. Naval Submarine Base, New London, Connecticut, REPORT NO. 285, PILOT STUDIES OF A SCOTOPIC SENSITIVITY TEST by G. Fooks, E. J. Sweeney and F. L. Dimmick.</p> <p>Rpt No. 1, Subtask 4, Bureau of Medicine and Surgery, Navy Dept., Project NM 23 01 20, June '57, 7 pp, plus iii, 6 tables, 3 refs.</p> <p>A new test of night vision sensitivity has been devised, that is based on data obtained in a series of experiments reported by this Laboratory. Those findings indicated (1) that sensitivity in the visual field must be sampled in two dimensions and (2) that size and brightness of the test areas can be used interchangeably. The present preliminary studies were designed to determine (1) whether a sampling procedure would give the same indication of the distribution of sensitivity as the more extended psychophysical techniques; (2) whether reliable differences in individual scotopic sensitivity were indicated; (3) whether multiple stimuli could be presented as a time-saving device; and (4) whether one or two testing sessions would give an adequate score. The results show (1) that the sensitivity scores correlate well with the psychophysical findings; (2) that significant individual differences in scotopic sensitivity exist; (3) that multiple stimuli do not produce any decrement in the sensitivity scores; and (4) that two testing sessions serve to differentiate individuals adequately.</p>	<p>1. Scotopic sensitivity test</p> <p>2. Night Vision, further tests techniques for</p> <p>I. Fooks, Gilbert II. Sweeney, Edw. J. III. Dimmick, Forrest L.</p> <p>DISTRIBUTION: Copies obtainable from USN MRL, New London, Conn.; also from DSC, ASTIA, Dayton, O.</p>	<p>U.S. Naval Medical Research Laboratory, U.S. Naval Submarine Base, New London, Connecticut, REPORT NO. 285, PILOT STUDIES OF A SCOTOPIC SENSITIVITY TEST by G. Fooks, E. J. Sweeney and F. L. Dimmick.</p> <p>Rpt No. 1, Subtask 4, Bureau of Medicine and Surgery, Navy Dept., Project NM 23 01 20, June '57, 7 pp, plus iii, 6 tables, 3 refs.</p> <p>A new test of night vision sensitivity has been devised, that is based on data obtained in a series of experiments reported by this Laboratory. Those findings indicated (1) that sensitivity in the visual field must be sampled in two dimensions and (2) that size and brightness of the test areas can be used interchangeably. The present preliminary studies were designed to determine (1) whether a sampling procedure would give the same indication of the distribution of sensitivity as the more extended psychophysical techniques; (2) whether reliable differences in individual scotopic sensitivity were indicated; (3) whether multiple stimuli could be presented as a time-saving device; and (4) whether one or two testing sessions would give an adequate score. The results show (1) that the sensitivity scores correlate well with the psychophysical findings; (2) that significant individual differences in scotopic sensitivity exist; (3) that multiple stimuli do not produce any decrement in the sensitivity scores; and (4) that two testing sessions serve to differentiate individuals adequately.</p>	<p>1. Scotopic sensitivity test</p> <p>2. Night Vision, further tests techniques for</p> <p>I. Fooks, Gilbert II. Sweeney, Edw. J. III. Dimmick, Forrest L.</p> <p>DISTRIBUTION: Copies obtainable from USN MRL, New London, Conn.; also from DSC, ASTIA, Dayton, O.</p>
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